Tube for use in fluid evaporation techniques, in particular food fluid

BACKGROUND OF THE INVENTION

The present invention concerns a tube for use in fluid evaporation techniques, in particular food fluid.

When a food fluid such as a sugary or milk liquid is evaporated, the heat exchanges on each side of the evaporating tube are very high because of the high energy balances used in this field.

In addition, when the fluid is evaporated, mineral and/or organic deposits are formed, which it is necessary to remove by means of repeated cleaning and disinfection operations in particular in the dairy field. The cost of the cleaning operations is high because of the quantity of water and cleaning products needed. In the case of a sugar refinery, processing sugar cane or beet, and in spite of the use of antifurring chemical products, the production has to be stopped in order to carry out the operations of cleaning the exchange tubes.

A method of manufacturing a so-called fluted tube is known, in which a base metallic strip is corrugated, in the direction of the width, between two pairs of rollers having flutes. The corrugated metallic strip is then rolled, also in the width direction, in order to form a tube having a corrugated profile in section. The purpose of the tube thus produced with the

corrugated strip is to increase the heat exchange surface for the same nominal tube diameter.

In this example, the production of the corrugations requires the use of a relatively thin strip of sheet metal, around 0.5 mm, in order to shape the corrugations. Because of this, the tube produced from a thin metal sheet entails a risk of perforation when corrosion occurs by pitting of the tube following successive pickling treatments. The corrugation also has the function of a stiffener, which allows the use of a thin base metallic sheet.

In another example embodiment, one of the rollers has a rectilinear generator line parallel to its axis of rotation and the other roller has grooves intended to form the said flutes on one face of the strip of laminated steel. The tube thus produced from the laminated strip has grooves only externally, the said grooves having the purpose, also in this case, of increasing the heat exchange surface of the tube for the same nominal diameter.

In this example the flutes formed locally generate a significant reduction in the thickness of the tube in the hollow of the said flutes and, in the technical field in question, gives rise to a risk of perforation when corrosion by pitting occurs.

A technique of grooving by cutting on the surface of a tube is also known. In this case also the grooving gives rise to a relatively great reduction in the thickness of the metal sheet of the tube and risks of perforation when corrosion by pitting occurs.

In the examples of known tubes of the prior art the function of grooving and corrugation is to increase the heat exchange surface without taking account of the wettability of the fluid.

SUMMARY OF THE INVENTION

The aim of the invention is to propose a tube made of welded stainless steel, which can be used in evaporators, notably in the sugar refining and dairy industries, the tube having an improved surface quality and a structure for its exchange surface ensuring an also improved heat exchange quality.

The object of the invention is a tube made of welded stainless steel which can be used in fluid evaporation techniques, in particular a food fluid, which is characterised in that it has, on at least one of its external or internal heat exchange surfaces, mostly smooth, localised means of accumulating and draining away condensations created on the smooth heat exchange surface.

The other characteristics of the invention are:

- the condensation accumulation and drainage means are distributed longitudinally to the said tube and uniformly,

- the condensation accumulation and drainage means consist of elevations in the form of shoulders extending over the length of the said tube and whose height is less than 0.5 mm and preferably less than 0.2 mm,

- the condensation accumulation and flow means consist of hollow impressions distributed over the length of the said tube,

- the impressions have a width of between 0.2 and 1 mm, occupying, in a distributed manner, less than 50% of the periphery of the said tube,

- the impressions have the shape of a rounded bowl,

- the condensation accumulation and flow means consist of steps, distributed at the periphery of the tube and occupying less than 50% of the periphery of the said tube,

- at least the surface opposite to the surface having the localised condensation accumulation and flow means of the tube has a roughness of less than 0.2 μm, of the 2R bright annealing type.

The invention also concerns a method for improving the heat exchanges in a heat exchanger for evaporating a fluid, in particular in the food industry, the exchanger having tubes intended for the heat exchange, characterised in that:

- there are produced, on at least one of the smooth surfaces of the exchange tubes, localised condensation accumulation and flow means, means intended to attract, by capillary attraction, the film of condensed liquid which is deposited uniformly on the mostly smooth surface of the tube;

- the said film of condensed liquid is drained away by the localised condensation accumulation and drainage means.

Another characteristic of the invention is:

- on at least one of the smooth surfaces of the exchange tubes at least one elevation is produced in the form of a shoulder extending over the length of the said tube and whose height is less than 0.5 mm and preferably less than 0.2 mm, an elevation defining a longitudinal impression whose edge attracts by capillary attraction the film of condensed liquid which is deposited uniformly over the mostly smooth surface of the tube.

The following description comprising the accompanying figures, the whole given by way of non-limitative example, will give a clear understanding of the invention.

BRIEF DESCRIPTION OF THE DRAWING

Figures 1, 2 and 3 each present, in section, an example of a tube made from stainless steel according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the shaping of a stainless steel tube able to be used in fluid evaporation techniques, in particular a food fluid, the shaping line of the tube, from a steel strip, includes means of rolling and welding the strip edge to edge. According to the invention, the line has a mechanical assembly comprising a so-called upper flat roller and a so-called lower roller. The so-called lower roller for example has equidistant projections or grooves of low height forming between them smooth surfaces, smooth surfaces mostly occupying the surface of the strip. The two rollers are adapted to the width of the starting steel strip, a starting strip whose width corresponds to the mean perimeter of the tube to be produced.

In the example embodiment according to the invention, the mechanical assembly is placed at the head of an induction, laser or TIG welder.

With the mechanical assembly, on at least one of the surfaces of the stainless steel strip, localised condensation accumulation and drainage means are produced, consisting for example of linear impressions sufficiently spaced apart from each other to release a mostly smooth internal or external surface of the tube.

Figure 1 presents in section a tube part 1 according to the invention on which, for example, the localised condensation accumulation and flow means are produced on the external peripheral surface 5 of the tube which also has an internal peripheral surface 7.

The condensation accumulation and drainage means consist, in this example embodiment, of elevations 2 and 3 in the form of shoulders extending over the length of the said tube and whose height is less than 0.5 mm and preferably less than 0.2 mm. The elevations 2 and 3, in the figure, define impressions 4 whose depth is less than 0.5 mm and preferably less than 0.2 mm. It will be noted that the slightness of the depth of the impression does not in any consequential way modify the total thickness of the sheet metal of the tube. It is possible to conceive of the production of a deeper impression, but this presents only drawbacks, notably the appearance on the tube of thin zones.

The impressions 4, preferably distributed longitudinally on the tube 1, uniformly on its periphery, preferably have a width of between 0.2 and 1 mm, occupying in a distributed manner less than 50% of the external periphery of the tube 1. In the example presented in Figure 1, the impressions 4, in the form of a rounded bowl, preferably occupy approximately 20% to 25% of the external peripheral surface 5 of the tube.

The capillary attraction effect, generated by the edge of the impression 4, moves the vapour condensation film which forms on the external peripheral surface 5 of the tube, towards the impression 4. The impression 4 behaves like a channel.

The impression, preferably in the form of a bowl, has the advantage of effectively attracting the film of fluid distributed over the surface of the tube so as to form droplets which will be channelled and easily removed.

In other words, the purpose of the invention is to discharge, as rapidly as possible, the drop of water which forms on the surface including the impressions so that it is replaced as quickly as possible by vapour which will change from the vapour phase to the liquid phase.

If the wettability were great, the drop would have a tendency to spread over the surface and therefore not to be removed - the object of the invention prevents this phenomenon of wettability - the surfaces of the stainless steel tube undergo no heat treatment in order to accentuate the discharge.

Other condensation accumulation and drainage means can be envisaged such as for example the production of steps 6

distributed over the length of the tube 1 as presented in Figure 2.

The steps consist of two elevations 2 and 3 having a height of less than 0.5 mm, preferably less than 0.2 mm, and a width occupying, in a distributed manner, less than 50% of the periphery of the said tube and preferably between 20% and 25% of the surface of the tube.

In the example, the internal surface of the tube has a roughness of less than 0.2 μm, of the 2R bright annealing type, a surface which is not disturbed by the production of impressions.

The tube is produced from a strip of sheet metal with a thickness of between 1.3 and 1.5 mm made from stainless steel of the ferritic or austenitic type such as a AISI 439, 304, 304L or 316L, although some steels seem to be preferable to others, as will be demonstrated below.

The production of the impression causes, because of the dimensions thereof, no area of work hardening of the base steel, and no increase in the hardness of the steel. In addition the impression causes practically no modification to the thickness of the wall of the tube, which prevents any risk of premature piercing of the tube if there is a risk of corrosion by pitting.

In this embodiment, because of the low level of disturbance caused by the production of the impression, it is possible to modify the external appearance of a cylindrical tube in order to increase the heat exchange capacity of the said tube,

without excessively modifying the surface state of the internal part of the tube.

Under these conditions, the internal part of the tube offers a surface limiting furring and facilitating cleaning operations, the external part of the said tube offering a practically smooth cylindrical surface which, because of the existence of the impressions, provides an increase in the heat exchange by draining and removing the condensation which forms continuously on the tube in its function of "hot" heat exchanger from vapour.

The tube according to the invention can have means of accumulating and draining off fluid on its two external and internal surfaces 5 and 7, respectively, so as to be able to be used, as required, in the two functions of "hot" or "cold" heat exchanger.

In the context of "cold" heat exchangers with a change of phases of fluid, use will be made of tubes having on their internal surface 7a the localised means 4a of accumulating and draining off the condensation as shown in Fig. 3.

In the context of a study on the furring of tubes in contact with sugary juice, it is found that the deposition consists mainly of $CaCO_3$. A mechanism including three phases was revealed:

- an initiation of the deposits of fur, which corresponds to an increase of the evaporatory rate. This initiation depends on the surface properties of the tube such as microroughness and surface chemistry. There are two types of initiation, one

mineral of the $MgO-CaCO_3-SiO_2$ type for surfaces of the 2B and 2D type, pickled or not, the other mixed of the $CaCO_3$ plus organic materials type, for surfaces of the 2R and electropolished type,

- an equilibrium between the kinetics of furring and the separation of layers of fur. At this stage, the composition of the steel of the tube is an important parameter since the thermal coefficient and coefficient of expansion will act on this equilibrium.

- a phase in which the furring predominates on the detachment of the layers of fur.

The tube according to the invention has the advantage of furring up less compared with the other tubes tested. The reduction in furring is by a factor of 2 to 3, which increases the evaporation rate by close on 25%.

From the point of view of cleaning, a difference in kinetics is found and consequently the consumption of water necessary for removing high deposits of fur can be reduced by half.

The cleanability of the tubes depends both on the chemistry and the topography of the surface. This is because, according to the surface chemistry of the tube, the initiation of the deposits of fur differs and consequently the ruptures caused by the water under pressure, in the deposition of fur, are more or less easy. The roughness of the internal surface is an important factor for the elimination of the deposit. The lower the mean surface roughness, the more easy the surface will be to clean. Because of the low level of deformation caused on

the external surface when the impressions are produced, the internal surface state is little or not modified.

The measurements of water consumption do indeed confirm the mechanisms governing the ease of cleaning of the surface, namely the surfaces of the tubes produced from AISI 439 stainless steel enriched in oxide of Si and having a mean roughness Ra of 0.2 μm will be furred by a deposit of $CaCO_3$ associated with the organic material. This deposit is more friable and therefore more easily eliminated than a completely mineral deposit which preferentially forms on the surfaces of a tube produced for example from AISI 304 steel enriched in iron or chromium oxide having a mean roughness Ra of less than 0.4 μm. Consequently the volumes of water necessary for removing the deposits on tubes made from AISI 439 2R steel are half those measured for removing the deposits on pickled AISI 304 steel tubes.

Thus superior characteristics of a tube made from steel with an AISI 439 composition are thus revealed, in comparison with a tube made from a steel with an AISI 304 composition.

The tube according to the invention provides:

- a gain of at least 25% with regard to the energy balance of the evaporation chambers;

- a limitation in the liquid discharges to be re-treated,

- a reduction in the cleaning frequencies, notably for sugar cane refineries not using any antifurring product,

- a reduction in furring,

- easier and faster cleaning.